Comparison of Magnetic Anisotropy by X-Ray Magnetic Linear Dichroism.

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BACKGROUND

Over the last years x-ray magnetic circular dichroism (XMCD) has been established as a technique to reliably determine the direction and the size of the local spin and orbital magnetic moment of a each element in a sample. An interesting property of magnetic systems is the magnetic anisotropy manifested in the observation that spins tend to align parallel to a certain crystal axis to minimize their energy. The origin of the anisotropy lies in the coupling of the electron spin to the orbital moment and thus the crystal lattice. In principal the anisotropy energy can be determined from the difference of the orbital moment measured along different crystal axis. Practically this is rather difficult because of the small size of the orbital moment. Recently experiments employing the x-ray magnetic linear dichroism (XMLD) have been suggested and some very promising first results were published [1,2]. Linear dichroism is not sensitive to a net magnetic moment, but only to the relative orientation between electric field vector and magnetic moment. It can thus be used to determine the energetic difference between two configurations in which the magnetic axes are oriented perpendicular to each other.

We studied the influence of thin films of Ni on the in versus out of plane anisotropy of $CoFe_2O_4$. In all these samples the spins prefer to align parallel to the surface, which is referred to as *in plane anisotropy*. However, we know from hysteresis loops measured using the magneto-optic kerr effect that it is easier to drag the magnetization out of the surface plane if a thin Ni layer is deposited (2nm). Therefore the sample covered with Ni should exhibit a smaller XMLD signal due to the smaller in plane anisotropy. The use of an elliptical undulator beamline offers the possibility to monitor the XMLD signal while rotating the electric field vector continuously from the easy axis of the sample (parallel to the surface) to the magnetic hard axis (perpendicular to the surface)

RESULTS

An external field of 2800Oe along the beam direction was applied to fully magnetize the sample. Dichroism spectra were acquired by switching the polarization between 90% plus and minus circular helicity (XMCD) or between fully horizontal and vertical linear polarization (XMLD). Figure 1 shows the comparison between magnetic circular and linear dichroism of Fe 2p in $CoFe_2O_4$. The net XMCD signal has a different sign for L_3 and L_2 absorption resonance. Sum rules relate the difference in XMCD signal to the net atomic magnetic moment. Another sum rule relates the normalized integral to the orbital moment. Because of the complicated line shape of the iron oxide resonances the accurate determination of the integral is difficult. An alternative is to use the XMLD signal which does not change its sign, because it is not sensitive to the net magnetic moment. In case of XMLD a qualitative determination of the orbital moment is possible only by observing the relative intensity of the two features within each resonance. It reaches a maximum when the anisotropy axis (easy axis) and the electric field are perpendicular to each other.

We now monitored the ratio while rotating the electric field vector away from the surface normal into the surface. Figure 2 shows the result. Both samples show a maximum XMLD signal when the electric field vector is perpendicular to the surface meaning that both samples show an effective in plane anisotropy. Of the electric field vector is rotated towards the sample surface, the XMLD follows the predicted $\cos^2$ dependence [1] for both samples. The absolute value of the XMLD intensity is increased in the sample with the thin Ni layer on top. This demonstrates that indeed the in versus out of plane anisotropy of the $CoFe_2O_4$ is changed by the Ni deposition. The fact that this behavior is also observed in XMLD rules out a pure change in so called *surface anisotropy* by the Ni deposition but that the interaction of the electronic structure of both systems is of importance.

References

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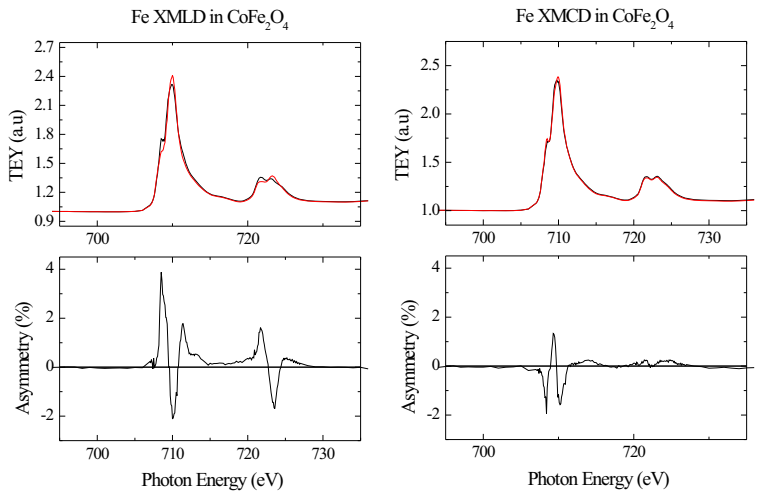

Figure 1: 2p absorption spectra of Fe in $CoFe_2O_4$. The left panel shows XMCD and the right panel the XMLD spectra. The absorption spectra acquired for each polarization are shown on the top. The bottom row displays their difference.

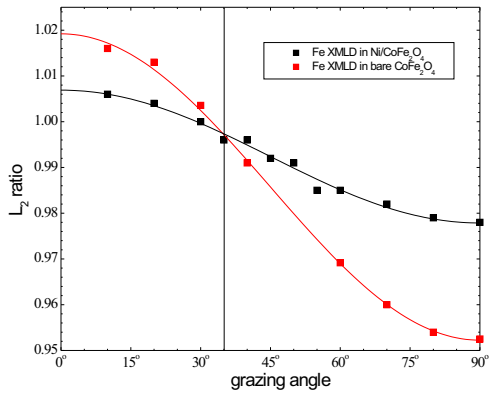

Figure 2: The angular dependence of the XMLD signal in $CoFe_2O_4$ (red) and with a 2nm thin Ni layer (black). The XMLD signal is maximal when the electric field vector is perpendicular to the surface indicating net in plane anisotropy. The absolute amplitude of the XMLD is smaller for the sample covered with Ni, because of the reduced anisotropy. The curves cross at the magic angle, where polarization effects do not play a role.